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HEXAGONAL FAST RESPONSE HEATERS FOR MANUFACTURING A MODULAR BLACK BODY EQUIPMENT

HP INC

Hexagonal Fast Response Heaters for manufacturing a modular Black Body equipment

3D printing technology is used to print 3D models with very different geometries. For being able to print parts within parts quality metrics, it is necessary to use an accurate & repeatable thermo-camera sensor. To calibrate and characterize this sensor is used an equipment named Blackbody, which represents an ideal reference source, with uniform temperature at many defined setpoints and known emissivity coefficient. This equipment is expensive and has limitations which makes impossible to integrate them in the printer.

In this publication we define a modular/stackable AlN heating element with hexagonal shape (Fig. 1) and black coated surface to manufacture a Blackbody equipment depending on the needs of each 3D printer design (depends on the printable area size and requirements).

Current solution is based on using a standard Blackbody which limits the characterization of the thermo-camera used in future 3D printers (Blackbodies with small surface are much more accurate. Blackbodies with higher surface represents better the dynamics of a 3D printer). Consequently, we can’t understand the behavior of the sensor within the printer environment. This affects directly to the PQ metrics obtained.

When a calibration according to different temperature contents is needed, a carboard screen with holes for the ROI (Region of interests) is used. The cardboard masks what is not needed but there is no control of temperature on these areas. Also, it is used sometimes another smaller blackbody on top of bigger one, but due to its height gives a different calibration focus, so it is not representative of plane of measurement.

Being able to manufacture a flexible Blackbody depending on the project needs (print size, 3D raw materials used, fusing agents, thermal camera specs …), allows us to develop and understand the thermo-camera sensor better for each new and different environment. This will lead to more repeatable PQ metrics and a better control process during the printing, even having different configurations between printers.

Also, by using modular heaters, we can play with different temperatures simulating fused parts and powders as it happens in the real printing. And this is confirmed to have an important effect on the thermo-camera readings.

The other problem solved is that this solution enables the printer thermal camera calibration being done by company services or by the end user acquiring a “modular Hexagonal Blackbody” to fullfil ISO 9000 requirements on industrial environments, where each module can be NIST calibrated and staking for different printers sizes.

Our idea is to manufacture the Blackbody with fast response hexagonal heaters and by locating one next to the other, thus creating the surface needed as shown in Fig. 2 (representing the printable area).

Circular and squared geometries where also considered but they have disadvantages respect hexagonal shaped modules. Circular shaped modules, although having a uniform temperature gradient along all directions (Fig. 3), have unheated gaps between heating modules (Fig. 4) which may lead to thermo-camera calibration inaccuracies. On the other hand, square shaped modules have less temperature uniformity at a given temperature than hexagonal modules (Fig. 5 and Fig. 6). Low temperature uniformity is undesirable because it may lead to a more complex or inaccurate temperature control system.

In conclusion, hexagonal shaped heating modules allow layout flexibility in the Blackbody equipment. Additionally, it makes more feasible to have a simpler temperature control system while increasing temperature uniformity and accuracy in the thermo-camera calibration.

The hexagons configuration can have different sizes. Small hexagon sizes will lead to have less heat free side spaces on a relative big print area (see Fig. 7).

The heating element stacking can be done in such a way that the print area is totally covered by heating elements as shown in Fig. 8.

If there was no free space around the print area to place an entire hexagonal heating element, the free non-heated zones on the edges can be filled by half-hexagonal heating elements (see Fig. 9).

So previous claim is showing that hexagonal is not a mandatory shape for this disclosure, but is the easiest manufacturable and stackable shape, with no free spaces) covering most of the print area.

The heating element, should be constructed by a material that has:

- Relatively high thermal conductivity
- Relatively Low electrical conductivity
- Relatively low thermal expansion
- Relatively high surface emissivity

To comply this, different materials can be used to cover the heater construction, such as ceramics (like aluminium nitride), quartz, aluminosilicate, mica, silicone, …

Also, to improve surface emissivity, some special paintings or coatings can be applied on the material surface (for example black paint).

In order to improve the thermal stability, on the depth axis the black body element can be relatively thick to increase the mass (Fig. 10).

To maximize the surface area of emission, surface pyramidal shapes could be added on the black body emitting surface (this last indication is already used in the commercial existing black body emitters but can be also used in our disclosed system too) (Fig. 11).

To improve the assembly and heat interface between each hexagonal heating element and avoid mistakes in the assembly process of the blackbody elements one next to the other (poka yoke), an edge interface can be added on the blackbody elements. As an example, here shown different options in Fig 12 and 13.

Also, electrical connection elements can be added on the black body elements to interconnect each one of them and reduce the number of external connections (see Fig 14).

Finally, the blackbody element can have one or more dependent or independent electrical heating circuits in order to compensate possible external conditions that force nonhomogeneous heat dissipation of the black body elements (see Fig. 15).

The advantages of this modular equipment are the following:

- To manufacture a custom modular/stackable blackbody equipment adapted within different printer requirements.
- The disclosed blackbody can either be external (and interchanged between different systems or printers) or integrated in the printer
- Relatively lower manufacturing cost compared to market existing blackbody elements
- To obtain a more robust and repeatable PQ metrics.

- Reduce TCO increasing production yield.
- The system can be used either in the production manufacturing line or by the service team or by the customer to calibrate their printer according ISO 9000.
- Can be used by other systems not related to 3D printing (for example, 2D printing, thermal camera manufacturing, etc.)
- Can have different referent temperatures in the same plane to calibrate & validate different contents (compensation on internal lens reflections)
- It allows different set points for different materials.

This solution could be applied to all 3D printers that work with thermal cameras as a method to improve thermo-camera predictability and so to improve TCO and to be more robust in PQ metrics.

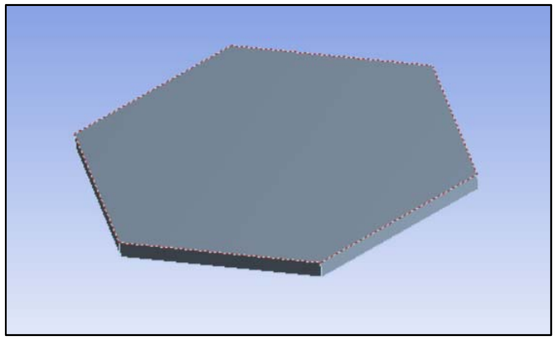

Fig. 1 Hexagonal shaped blackbody module.

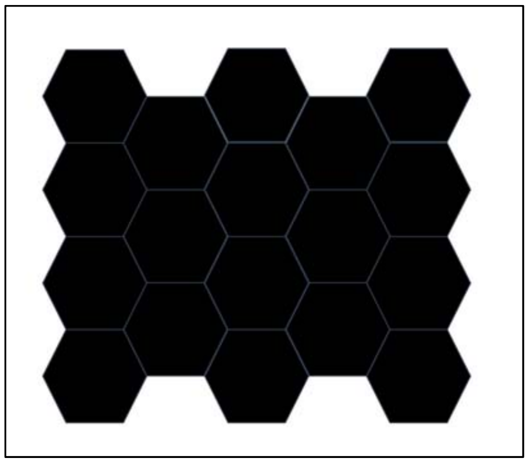

Fig. 2 Hexagonal shaped modules layout.

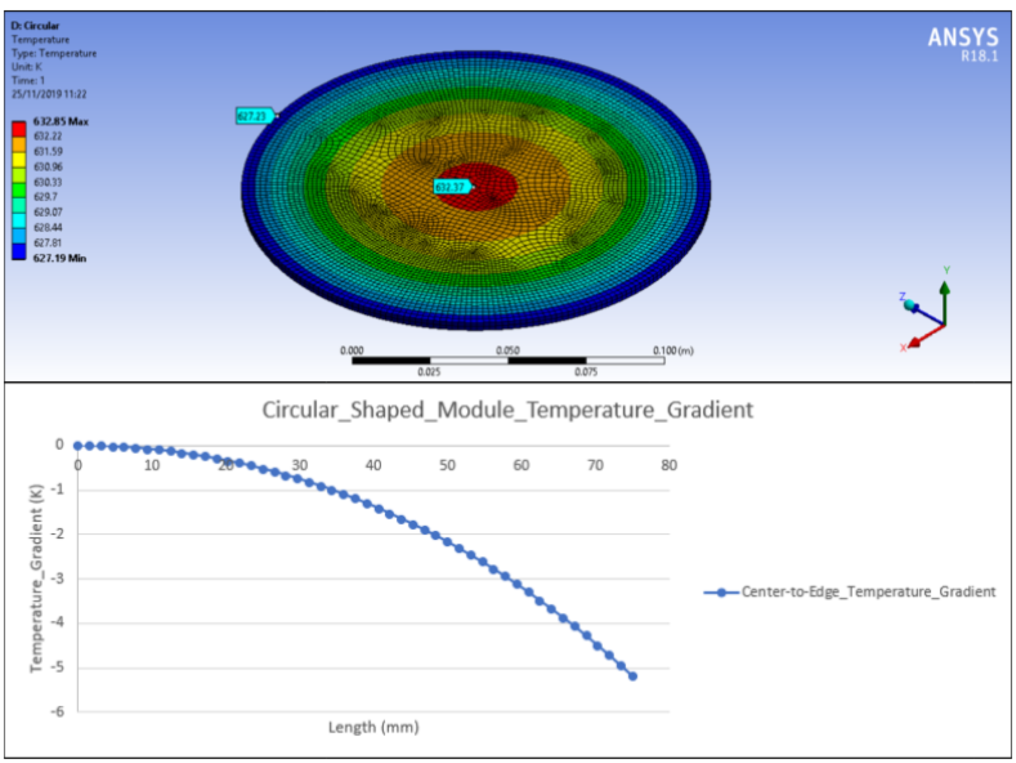

Fig. 3 Circular shaped module temperature gradient.

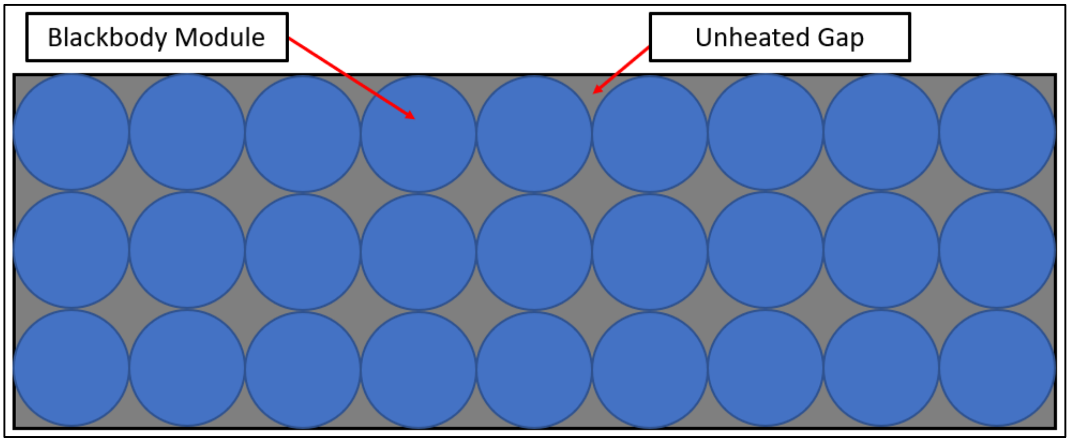

Fig. 4 Circular shaped modules layout.

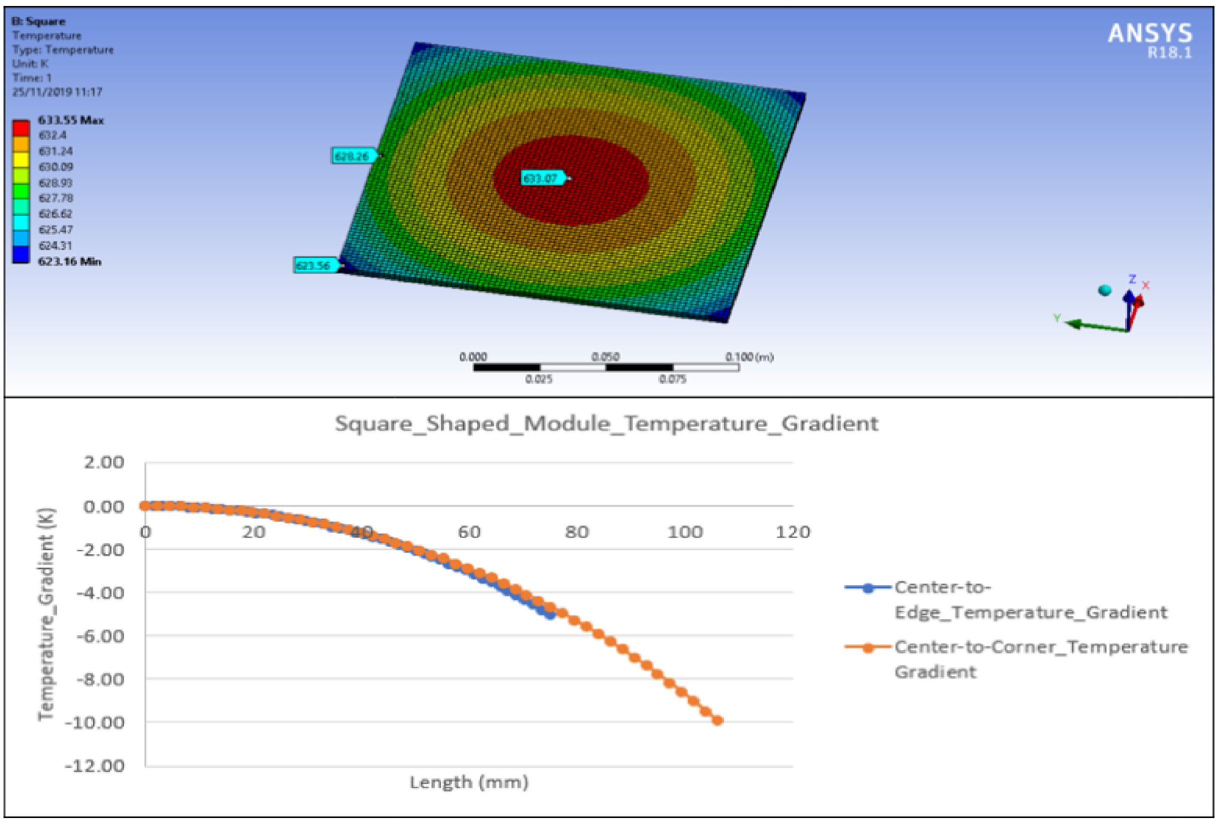

Fig. 5 Square shaped module temperature gradient.

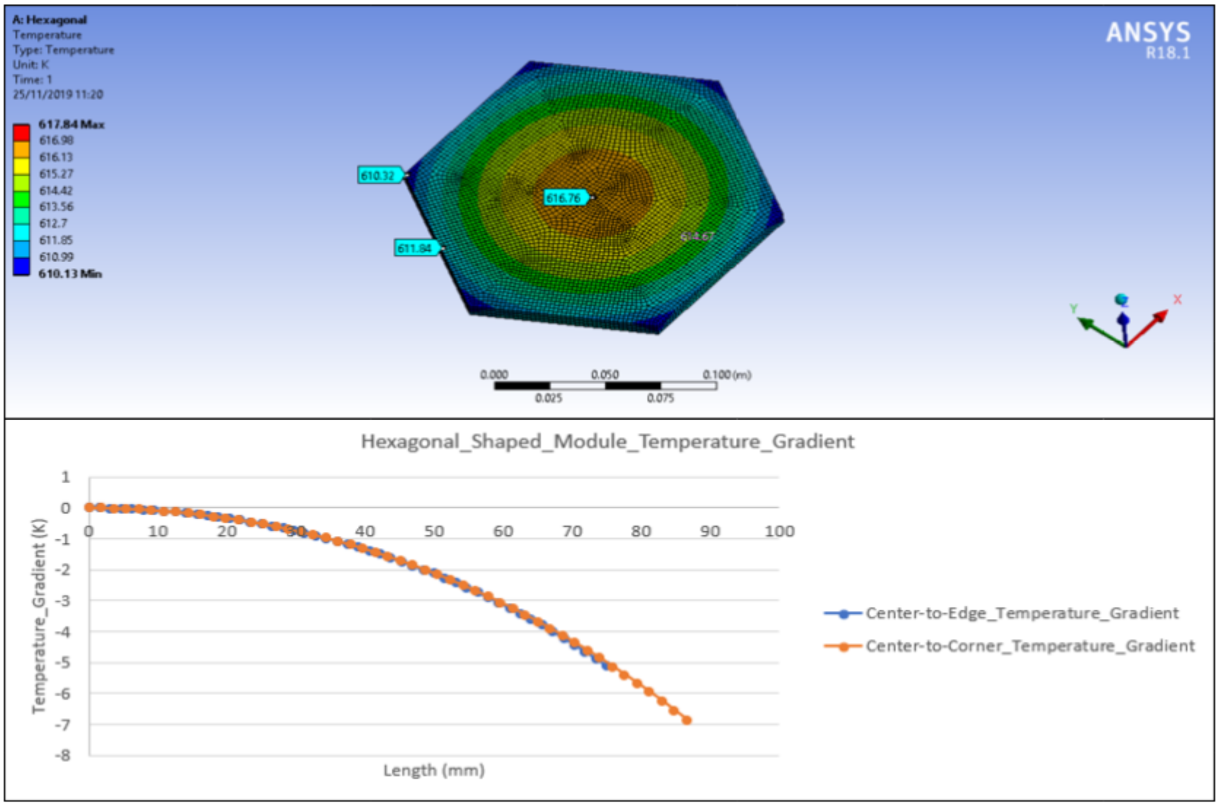

Fig. 6 Hexagonal shaped module temperature gradient.

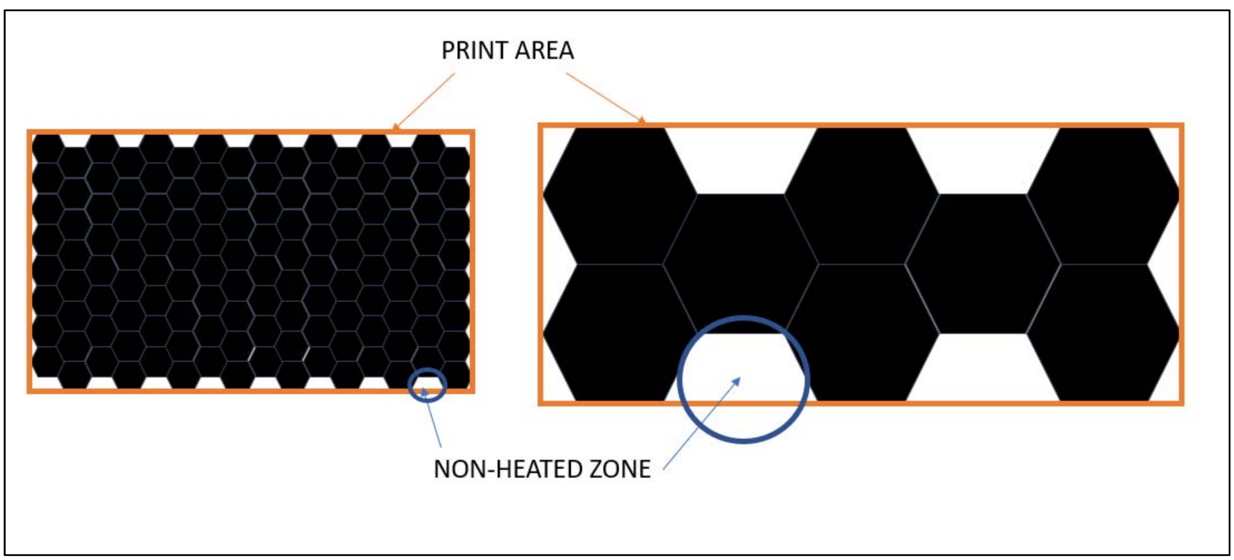

Fig. 7 Small hexagonal vs big hexagonal elements

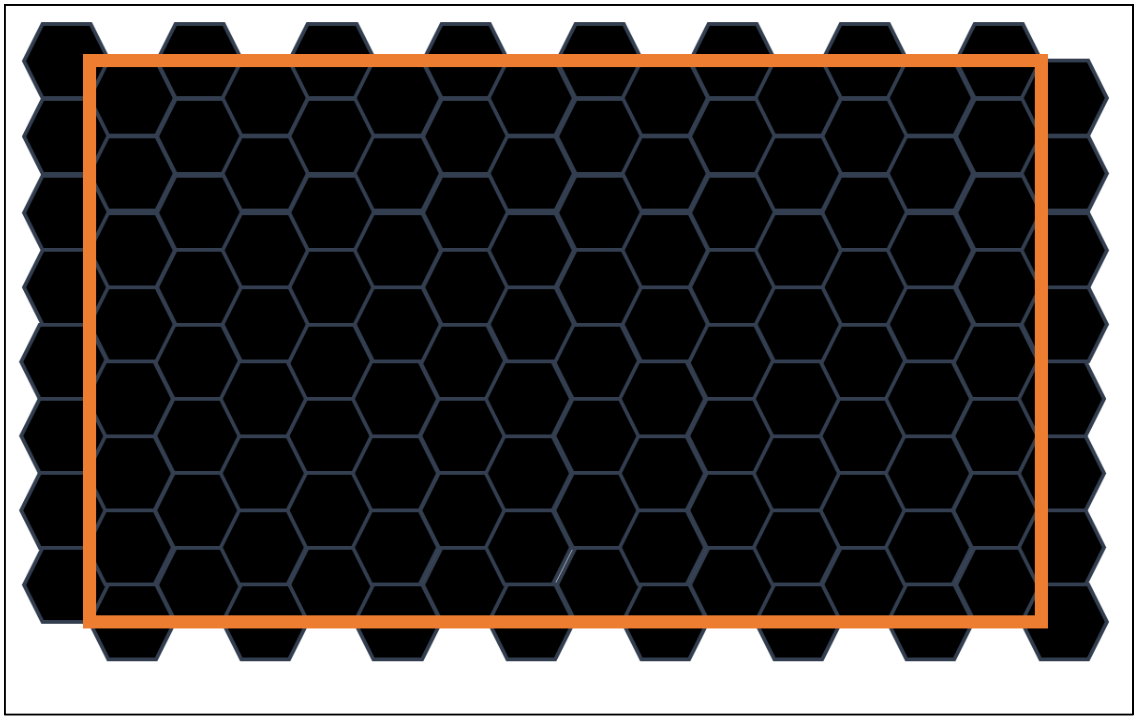

Fig. 8 Print area totally covered by hexagonal heating elements

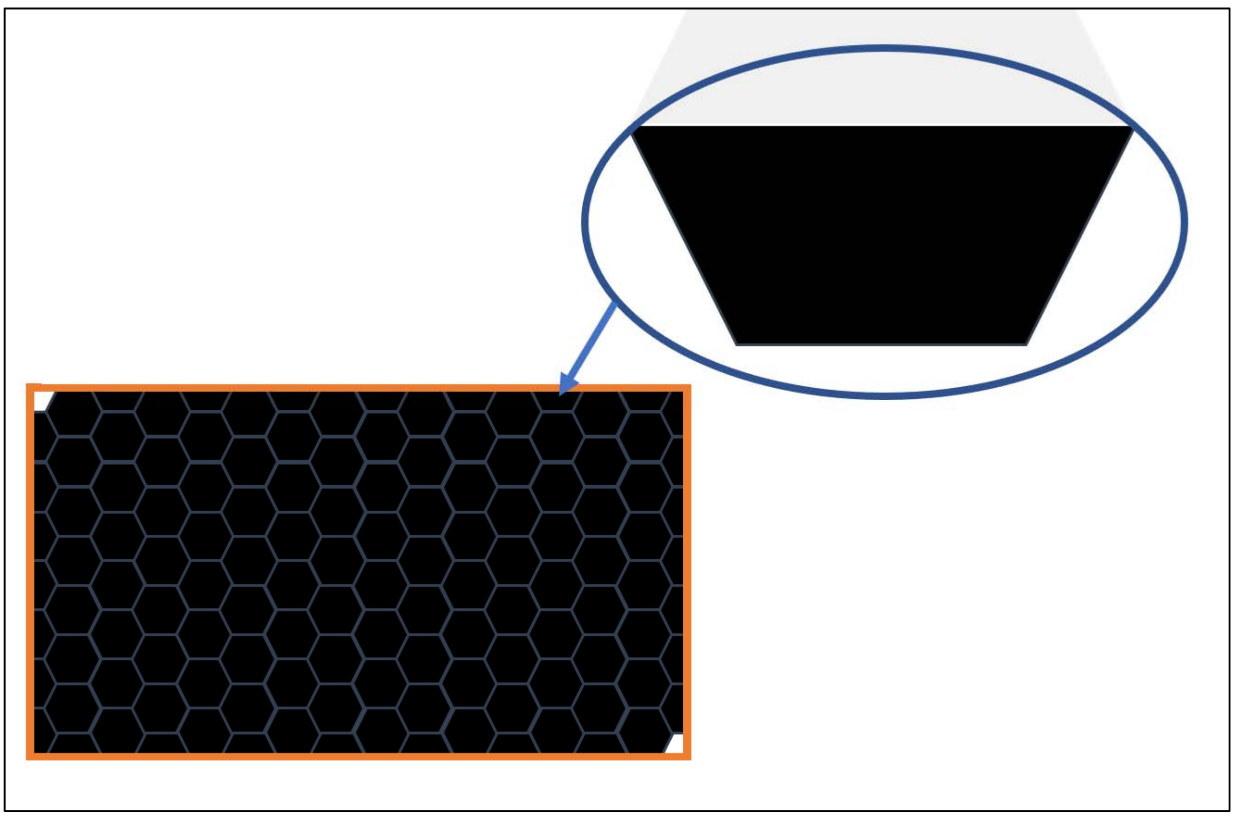

Fig. 9 Other shapes than hexagonal can be used.

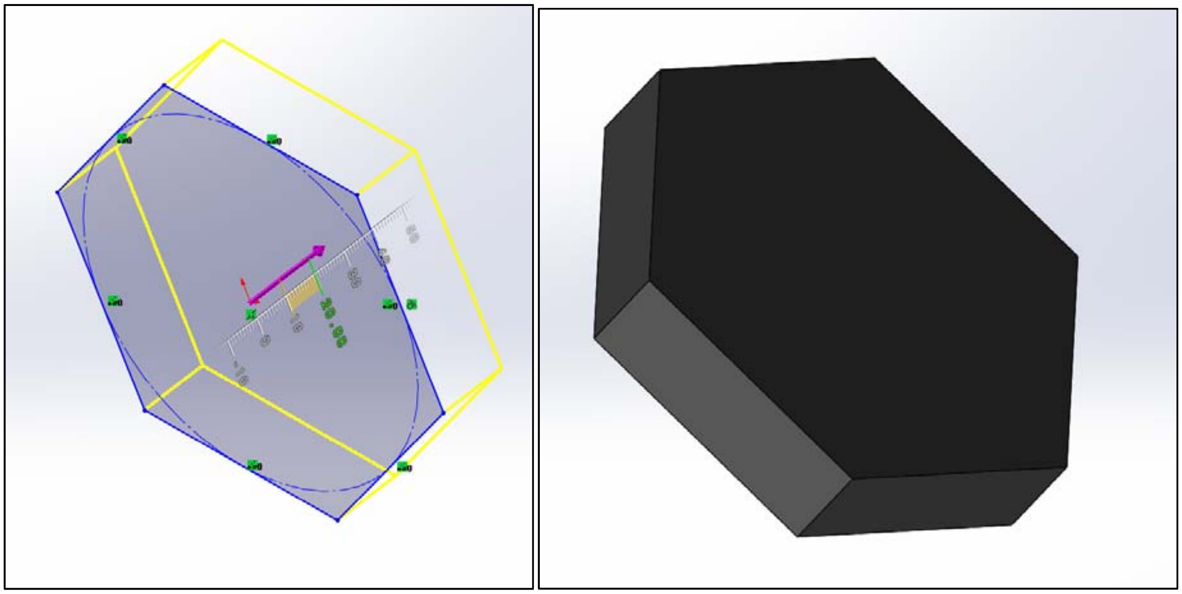

Fig. 10 Heating element thickness.

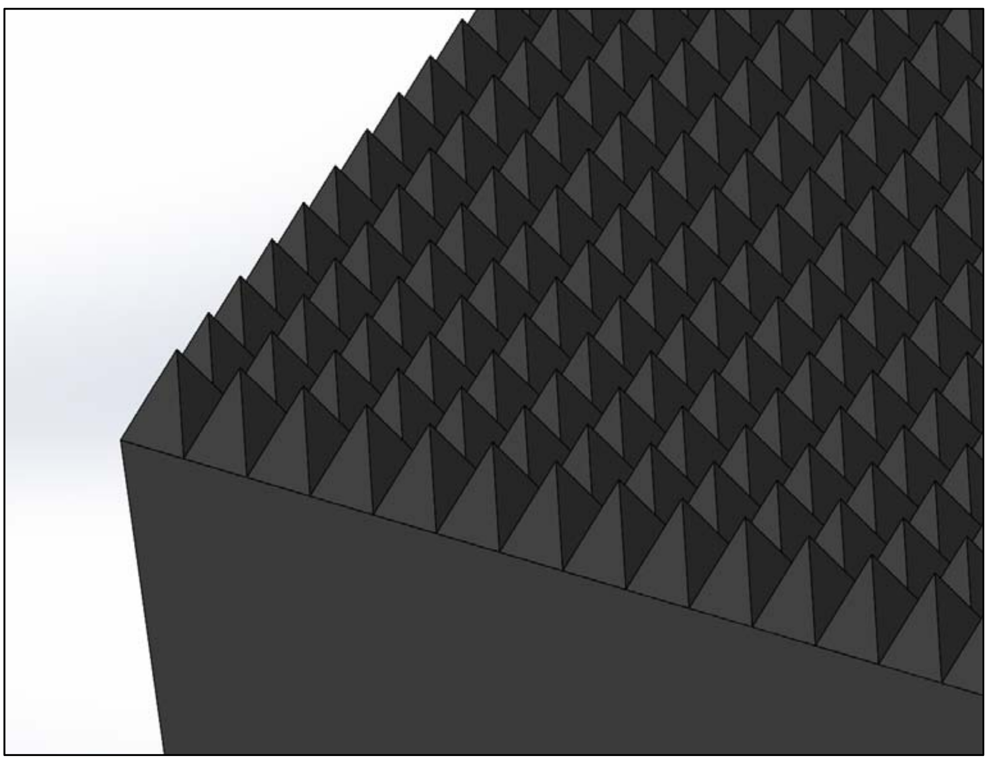

Fig. 11 “Pyramidal” surface shape.

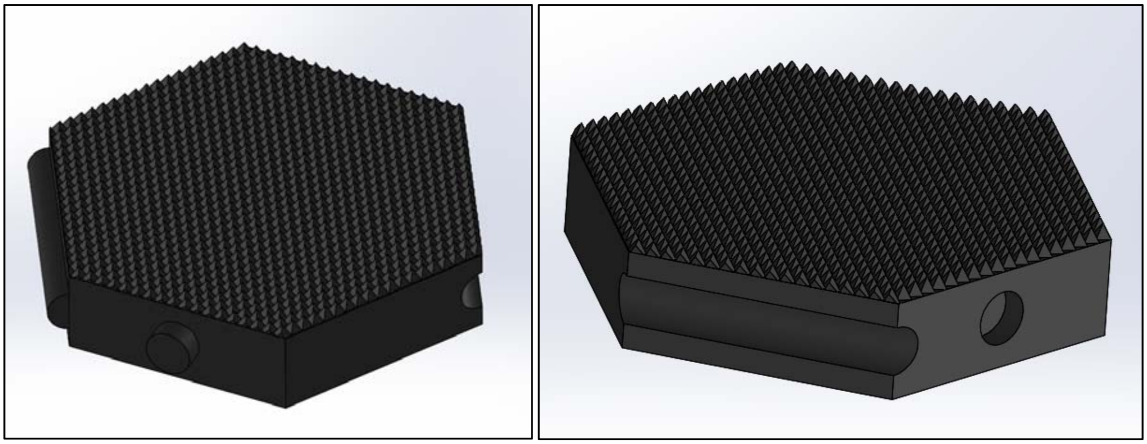

Fig. 12 Heating elements interface.

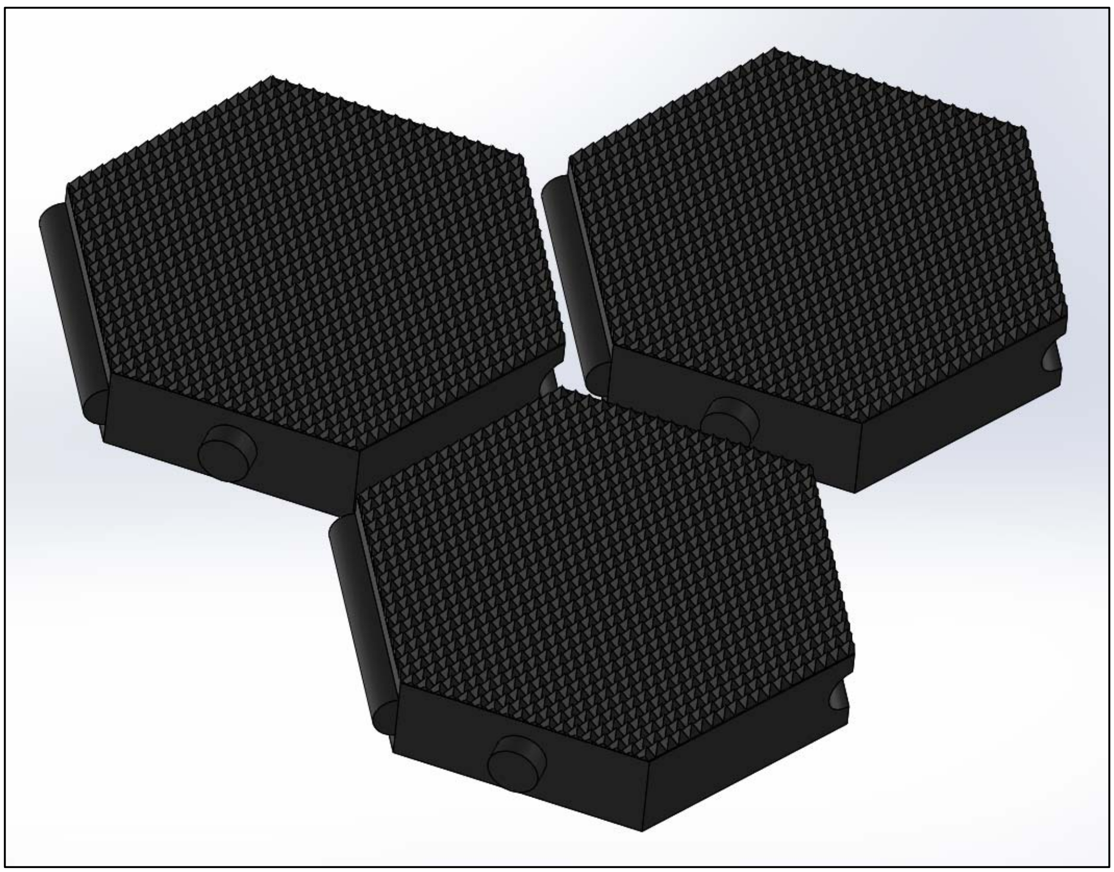

Fig. 13 Heating elements interface 2.

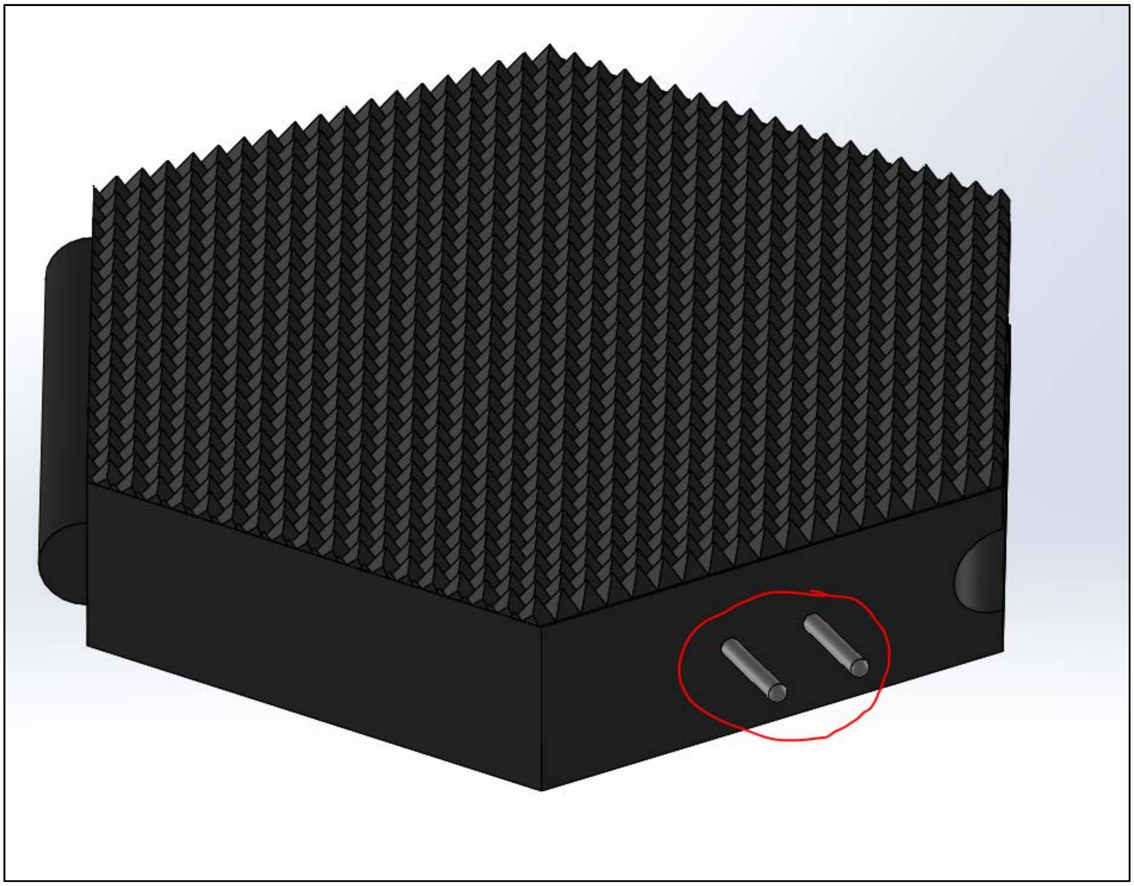

Fig. 14 Direct electrical connections between heating elements

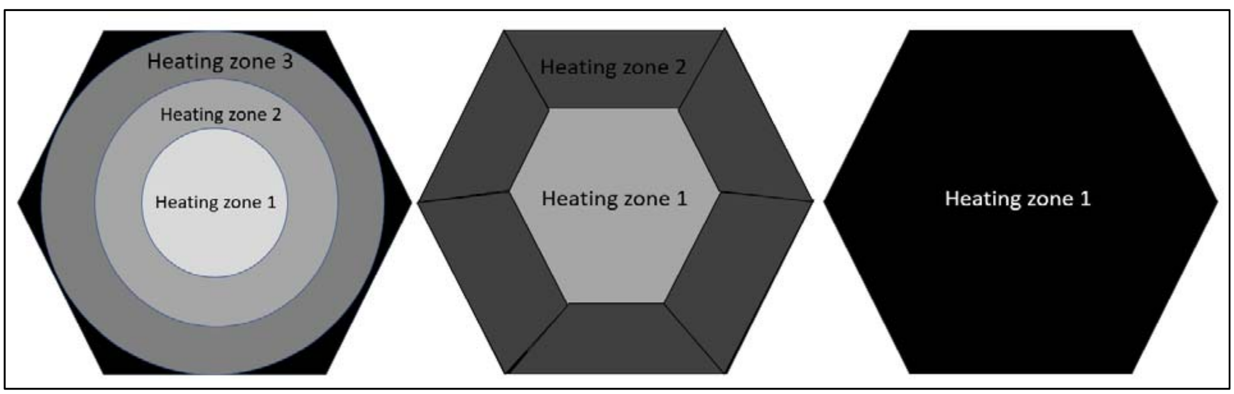

Fig. 15 Different heating zones in same heating elements

Disclosed by Davinia Font, Esteve Comas, Daniel Alejandro Poveda Pi and Jordi Blanch, HP Inc.